

*REAL-TIME DETECTION OF ORIENTATION DURING  
NEGATIVE BEHAVIORAL CONTRAST WITH  
KEY PECKING AND A TURNING RESPONSE*

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We developed a video system for real-time detection of a pigeon's orientation and for reinforcement of a "turning response." Using this system, negative behavioral contrast was found across key-peck and turning responses. In addition, turning away from the pecking key was detected by the system just after presentation of the negative discriminative stimulus on the key. The results suggest that avoidance of the discriminative stimulus in the constant component, which has been regarded as a causal factor for negative contrast (additivity theory), is not the primary factor for negative behavioral contrast of pigeons' key pecking, but may account for negative local contrast.

*Key words:* automated technology, video system, negative behavioral contrast, turning response, key peck, pigeons

Under typical two-component multiple schedules of reinforcement, two discriminative stimuli are presented successively. During presentation of one discriminative stimulus, a certain response is reinforced according to a schedule of reinforcement. During presentation of the other stimulus, the same response is reinforced by another schedule of reinforcement. In these multiple schedules, when the rate of reinforcement in one of the components is decreased, the response rate in the changed component decreases and the response rate in the other unchanged (constant) component increases. This inverse relation between response rate in the constant component and rate of reinforcement in the changed component is called positive behavioral contrast. Conversely, when the rate of reinforcement in one of the components is increased, the response rate in the other constant component decreases and is termed negative behavioral contrast.

In the study of behavioral contrast, two questions have been discussed. First, are positive and negative behavioral contrast con-

trolled by the same mechanism? Second, do positive and negative behavioral contrast occur in the same manner for topographically different responses?

Herrnstein's (1970) matching law implies that both types of contrast are explained by one mechanism: changes in relative rate of reinforcement across components. Therefore, positive and negative behavioral contrast should occur in the same manner for topographically different responses, differing only in the magnitude of contrast.

Staddon (1982) and Hinson and Staddon (1978) stated in the behavior-competition theory that both types of contrast are caused by reallocation of interim activities (such as wheel running for rats and locomotion for pigeons) from the component with the higher rate of reinforcement to the component with the lower rate of reinforcement. They also stated that contrast occurs in the same manner for topographically different responses.

On the other hand, additivity theory asserts that positive behavioral contrast is caused by an addition of responses elicited by the reinforcer (such as pigeons' key pecks when the reinforcer is grain) to the operant response baseline (Gamzu & Schwartz, 1973; Rachlin, 1973; Schwartz, 1975; Schwartz & Gamzu, 1977). In comparison to positive behavioral contrast, negative behavioral contrast is caused by avoidance of or escape from the discriminative stimulus that predicts that fewer posi-

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tive reinforcers will be presented, thereby decreasing the response rate to that stimulus. Therefore, additivity theory predicts that subjects will show an avoidance response to the discriminative stimulus in the constant component when the rate of reinforcement is increased in the changed component. Furthermore, additivity theory predicts that positive behavioral contrast occurs only for the responses that can be elicited by the reinforcer.

In previous examinations of the first question, it has been found that conditions that produce one type of contrast do not necessarily produce the other type of contrast (e.g., Ettlinger & McSweeney, 1981; King & McSweeney, 1987; Schwartz, 1975). These studies suggest that one mechanism cannot explain both types of contrast. (As mentioned above, additivity theory asserts two different mechanisms for the two types of contrast.) Experiments have been performed to test whether positive contrast is caused by an addition of responses elicited by the reinforcer to an operant response baseline (Keller, 1974; Manabe & Kawashima, 1982; Schwartz, 1978; Schwartz, Hamilton, & Silberberg, 1975; Spealman, 1976). The results of this research suggest that the addition of responses elicited by the reinforcer to the operant response baseline produces an increase in only the initial part of the constant component, a process termed *positive local contrast*. On the other hand, there have been no examinations of avoidance of the discriminative stimulus in the constant component under negative behavioral contrast. The present experiment examined whether subjects show any avoidance of or escape from the discriminative stimulus in the constant component when the rate of reinforcement is increased in the changed component.

Several studies have examined the second question. They suggested that positive and negative contrast do not occur in the same manner for key-peck, treadle-press, and bar-press responses in pigeons (Hemmes, 1973; Howard, 1979; McSweeney, 1978, 1982; McSweeney, Dougan, Higa, & Farmer, 1986; Scull & Westbrook, 1973; Westbrook, 1973). However, additional studies are needed to clarify the correlation between types of response topography and types of contrast with responses other than key peck, treadle press, and bar press.

To this end, we have developed a system

that can detect not only the positions but also the orientation of subjects in real time (cf. Pear, Rector, & Legris, 1982). The real-time detection of orientation makes it possible to detect activities that indicate changes in orientation of the subject (e.g., turning response, locomotion, etc.). Thereby, the present system can reinforce these responses automatically. In addition, the present system can detect an avoidance response away from the discriminative stimulus in the constant component under conditions of negative behavioral contrast.

In this paper, we describe the system and show pigeons' orientation in an experiment using negative behavioral contrast in which key-peck responses were reinforced in one component of a multiple schedule and either key-peck responses or turning responses were reinforced in the other component.

## METHOD

### *Subjects*

Three adult male homing pigeons were maintained at 80% of their free-feeding weights. The birds had free access to grit and water in their home cages.

### *Apparatus*

*Experimental chamber.* One black-painted experimental chamber (30 cm by 31 cm by 30 cm) was used. A response key was mounted on one wall behind a hole (2 cm diameter) at a height of 20 cm from the floor. A force of approximately 0.15 N activated a microswitch behind this key. The key could be transilluminated by red and green lights. Ten centimeters beneath the key were two openings (5 cm by 5 cm) to food hoppers that contained grain. The reinforcer was a 3-s period of access to grain. The left food hopper (the center of the opening was 7.5 cm from the left wall) was used for the turning responses, and the right hopper (7.5 cm from the right wall) was used for key-peck responses (see Figure 1). The ceiling was a black-painted rough net.

*Detection of orientation.* The pigeons' orientations were detected by the following method. Pigeons wore a harness with two white ping-pong balls attached. The harness did not prevent most activities. The ping-pong balls were positioned on the neck and the tail (see Figure 1). The back half of the ping-pong ball

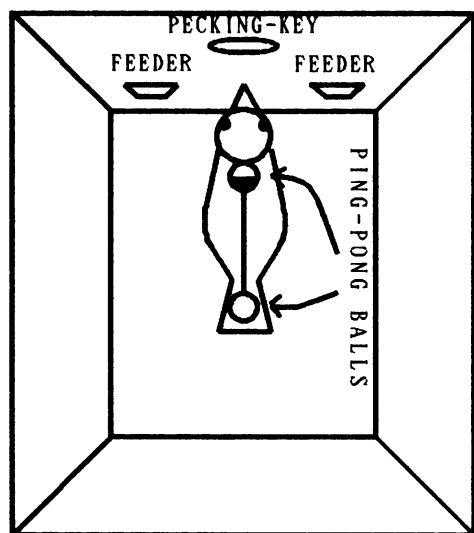


Fig. 1. Top view of a subject in the chamber. The two circles indicate ping-pong balls. The ceiling was a rough net painted black.

on the neck was painted black. A videocamera was situated 70 cm above the center of the ceiling on a tripod. The top-view image was translated to an X-Y image tracker. The X-Y image tracker calculated the X-Y coordinates of the two ping-pong balls (neck and tail), and transmitted the two X-Y coordinates to a microcomputer once every 0.2 s. The microcomputer recorded the two X-Y coordinates and calculated the angle of orientation. In this calculation, the arc-tangent was calculated based on the distance between X and Y coordinates of the neck and tail; the arc-tangent was then translated into the angle of orientation. The turning response was defined as a change from the area  $0^\circ$  through  $+45^\circ$  to the area  $0^\circ$  through  $-45^\circ$  passing through  $\pm 180^\circ$ , and vice versa (see Figure 2). At  $0^\circ$  the subject oriented its body directly toward the front panel, and  $\pm 180^\circ$  indicates orientation to the rear panel. A plus value indicates that the subject turned its body to the left side, and a minus value indicates turns to the right side. In this system, tracking errors occurred (a) when the subject's head accidentally covered a ping-pong ball on the neck, (b) when the angle of the subject's body relative to the floor was near  $90^\circ$  so that the ping-pong ball on the neck prevented detection of the one on the tail, and (c) when either of two points (neck and tail) moved more than the distance of about 176 cm in 1 s. When any of these errors occurred, the microcomputer

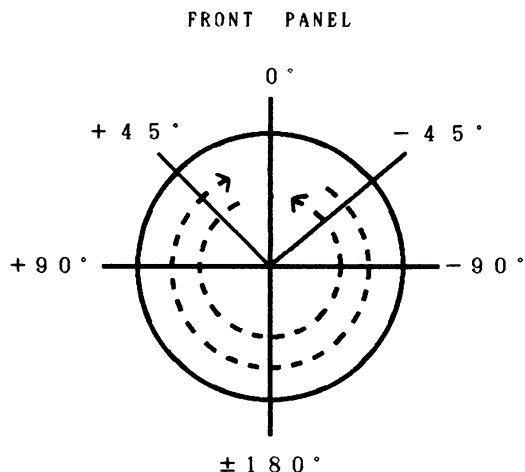


Fig. 2. The definition of turning. A turning response occurred when the angle of a subject's orientation changed from the area ( $0^\circ$  through  $+45^\circ$ ) to the area ( $0^\circ$  through  $-45^\circ$ ) through  $\pm 180^\circ$ , or vice versa.

automatically stopped the session, beeped, and turned off the keylight. Without delay, an experimenter reset the X-Y image tracker and proceeded with the session. These errors occurred rarely. Programs for experimental control and data collection were written in C language (Microsoft® C).

### Procedure

After all birds were habituated to the harness, they were trained to eat grain from the two food hoppers. Then, key-peck and turning responses were shaped by successive approximation. Subsequently, each subject was exposed to the following A-B-A-C-A-B-A sequence (see Table 1). In Condition A, the key-peck response was reinforced on a variable-interval 30-s schedule (VI 30) under one component (constant component; key color was green for Subject S1 and red for Subjects S2 and S3); no responses were reinforced under the other component (changed component; key color was red for Subject S1 and green for Subjects S2 and S3). In Condition B, the key-peck response was reinforced under a VI 30 schedule during the constant component, and the turning response was reinforced on a VI 30 schedule during the changed component. In Condition C, the key-peck response was reinforced on a VI 30 schedule during both components. To prevent chaining of key-peck and turning responses, a changeover delay (COD) of 3 s was used. Thus, a key-peck response

Table 1  
Experimental conditions. Experiments were conducted from top to bottom.

	Subject S1				Subjects S2 and S3			
	Component 1 (green)		Component 2 (red)		Component 1 (green)		Component 2 (red)	
	Key peck	Turn	Key peck	Turn	Key peck	Turn	Key peck	Turn
A	VI 30 <sup>a</sup>	EXT <sup>b</sup>	EXT	EXT	EXT	EXT	VI 30	EXT
B	VI 30	EXT	EXT	VI 30	EXT	VI 30	VI 30	EXT
A	VI 30	EXT	EXT	EXT	EXT	EXT	VI 30	EXT
C	VI 30	EXT	VI 30	EXT	VI 30	EXT	VI 30	EXT
A	VI 30	EXT	EXT	EXT	EXT	EXT	VI 30	EXT
B	VI 30	EXT	EXT	VI 30	EXT	VI 30	VI 30	EXT
A	VI 30	EXT	EXT	EXT	EXT	EXT	VI 30	EXT

<sup>a</sup> Variable-interval 30-s schedule.  
<sup>b</sup> Extinction.

was not reinforced during the first 3 s following the first peck just after a turning response, and vice versa.

All subjects received two sessions daily, 7 days per week. The first daily session began at about 7:00 a.m., and the last daily session began at about 4:00 p.m. Each session was terminated after each component had been presented 20 times. The component duration was 30 s. Components were alternated according to the Gellerman (1933) series. Each condition was in effect for 15 sessions.

RESULTS

Figure 3 shows the mean response rate (responses per minute) for key pecking and turning for the last five sessions of all conditions. Turning rates during the changed component increased when turning was reinforced (Condition B). Similarly, key-peck rates during the changed component increased when pecking was reinforced in the changed component (Condition C). On the other hand, key-peck rates during the constant component decreased

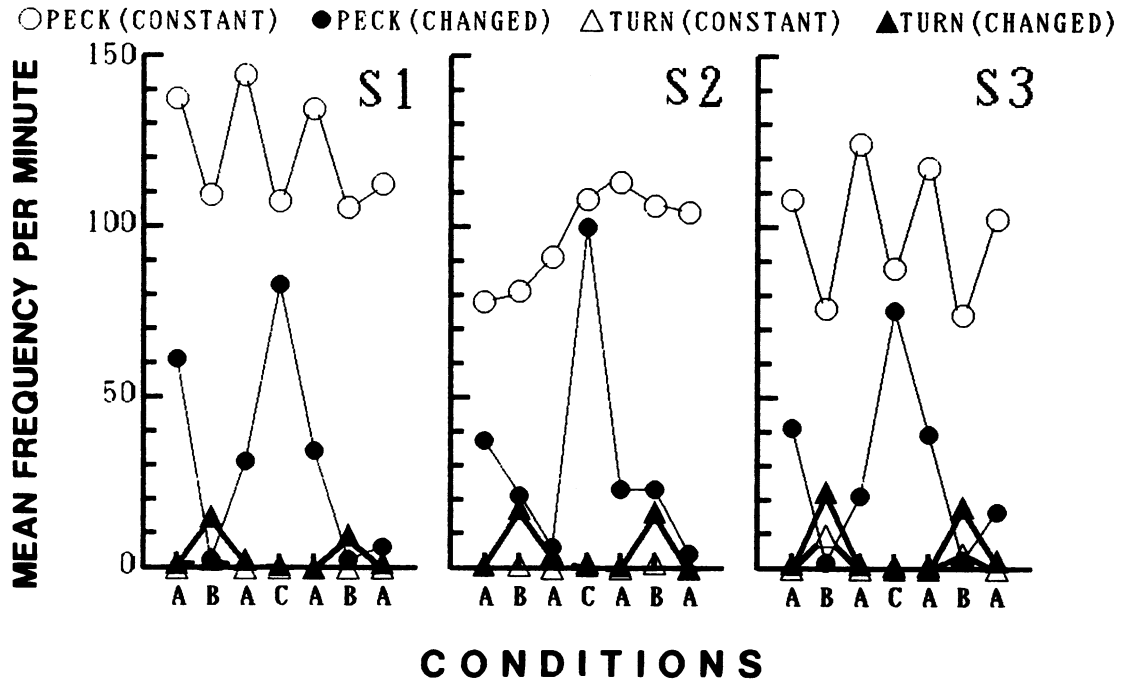


Fig. 3. The mean frequencies of the last five sessions for key-peck and turning responses under seven conditions. Circles indicate pecking response, triangles turning response, open symbols responses in the constant component, and filled symbols responses in the changed component.

when either key-peck or turning responses were reinforced in the changed component for Subjects S1 and S3. That is, negative behavioral contrast occurred for 2 subjects; Subject S2 showed no schedule interaction across components.

### *Analysis of Orientation*

Figure 4 illustrates subjects' angle of orientation and cumulative records of key-peck responses in the 19th and 20th components of the last session of each condition. In Figure 4, a curve from  $0^\circ$  to  $0^\circ$  through  $\pm 180^\circ$  indicates a full turn. If the subject kept a constant angle of orientation, the line was parallel to the  $x$  axis. Under components in which only key-peck responses were reinforced, the angles of orientation were near  $0^\circ$ , indicating that the subject oriented its body to the pecking key. On the other hand, under components in which turning responses were reinforced, the angles varied from  $0^\circ$  to  $\pm 180^\circ$  for Subjects S1 and S2. For Subject S3, the angles varied from about  $+45^\circ$  to about  $-45^\circ$  through  $\pm 180^\circ$ . This indicates that Subject S3 turned economically. Typical locomotion, in which the subject walks about in no particular orientation, was found for Subject S2 during the changed component (extinction) of the seventh condition. The line oscillated about  $+90^\circ$ .

Figure 5 shows the mean absolute degrees of angle under the constant component when preceded by the changed component and those under the changed component when preceded by the constant component. The data are based on the last three sessions. In Condition A (first, third, fifth, and seventh conditions) in the changed component (extinction), the mean absolute degree of angle abruptly increased in every case and gradually decreased, except for Subject S2 in the third and seventh conditions. These large angles of orientation in the initial part of the extinction components indicate that the subjects turned away from the pecking key just after presentation of the negative discriminative stimulus. These turning responses are also found in Figure 4 (see extinction component under Condition A). In the component in which turning responses were reinforced, the mean angles were large and the curves are parallel to the  $x$  axis, indicating continued turning throughout the component. Although the rate of key pecking during the constant component decreased in Condition C (see Fig-

ure 3), the mean absolute angles approximated those of Condition A.

Figure 6 shows the percentages of time that the subject oriented its body to various directions in the last session of the third, fourth, and fifth conditions (Conditions B, A, and C). The upper half of the vertical line of each grid indicates the area from  $-30^\circ$  through  $+30^\circ$ . The lower half indicates the area  $30^\circ$  to each side of  $180^\circ$ . The other half lines also indicate the areas having an arc of  $60^\circ$ . The length from the intersecting point describes the percentage of time that subjects oriented in a given direction. Intersection at the end of a line indicates that the subject oriented its body to that direction for the entire session (100%). If the subject oriented to each area for the same amount of time, the figure becomes a hexagon. During components in which the key-peck response was reinforced (each constant component and the changed component of Condition C), most of the time was allocated to the area from  $-30^\circ$  through  $+30^\circ$ . On the other hand, time was allocated to various orientations in the component in which turning responses were reinforced (changed component under Condition B). In Condition A, the percentages of time allocated to the area from  $-30^\circ$  through  $+30^\circ$  were smaller under the changed component, in which responses were not reinforced, than under the constant component, in which key pecks were reinforced. Under the changed component (extinction) in Condition A, Subject S2 allocated about 50% of the time to the left side from  $+30^\circ$  through  $+150^\circ$ . Although the rates of key pecks in the constant component for Subjects S1 and S3 were lower in Conditions B and C than in Condition A, the time allocated to the area from  $-30^\circ$  through  $+30^\circ$ , where key pecking occurred, was longer than in Condition A. The time allocated to the area from  $-30^\circ$  through  $+30^\circ$  under the constant component in Condition B for both subjects was shorter than in Condition A.

### DISCUSSION

Using the present video system, we found clear negative behavioral contrast of key pecking for 2 of 3 subjects when key-pecking or turning responses were reinforced in the changed component. This extended the generality of negative behavioral contrast for key-peck responses. However, King and Mc-

DEGREE OF ANGLE OF SUBJECT'S ORIENTATION

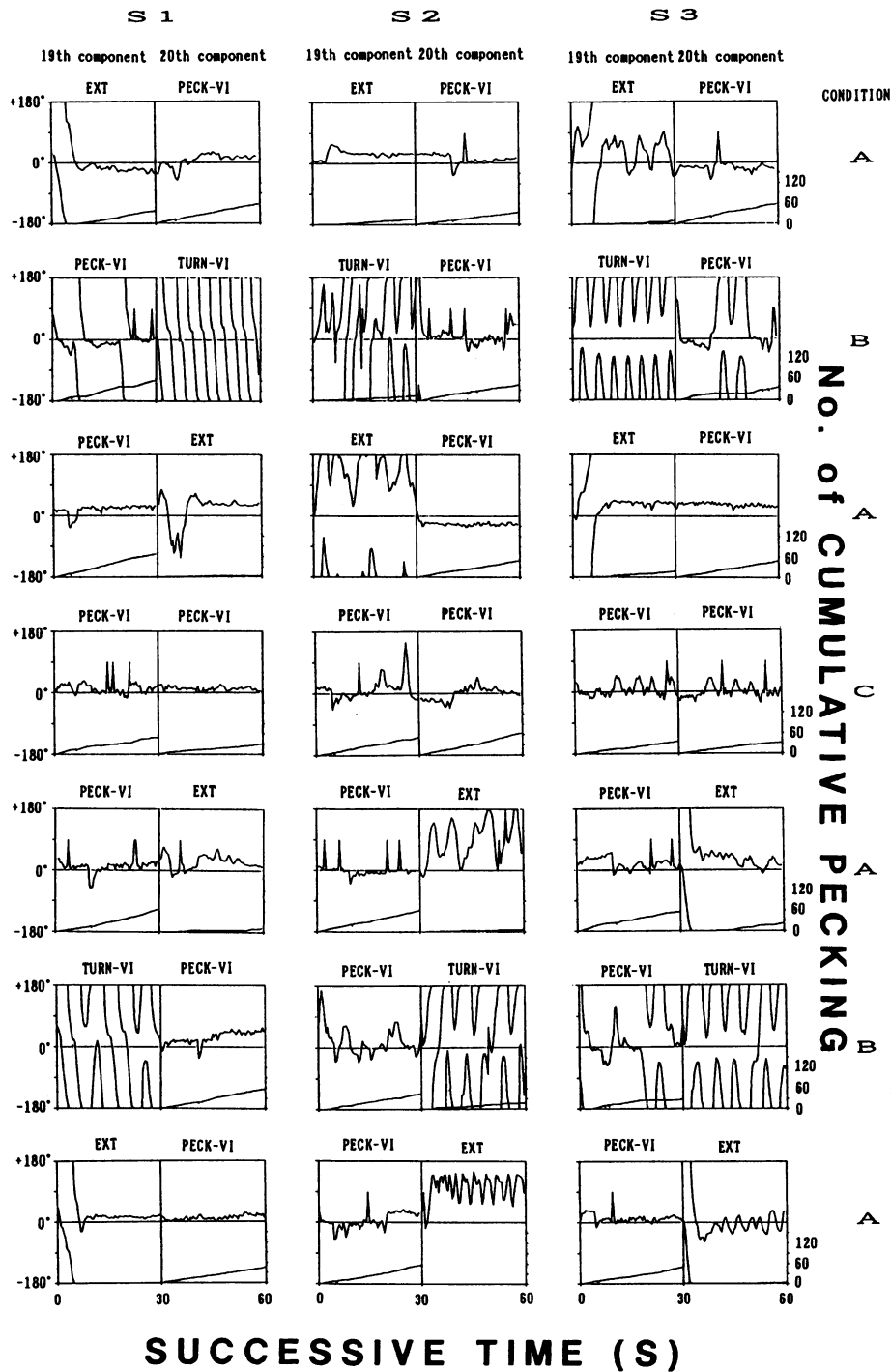


Fig. 4. The changes in angle and cumulative records for key-peck responses. The data of the 19th and 20th components are shown. EXT indicates components in which the schedule of reinforcement was extinction. PECK-VI indicates components in which the key-peck response was reinforced on a VI 30-s schedule. TURN-VI indicates components in which the turning response was reinforced on a VI 30-s schedule. Cumulative records have their origin in the bottom left corner of each half-panel; records for angle of orientation usually begin near the 0° position in each half-panel.

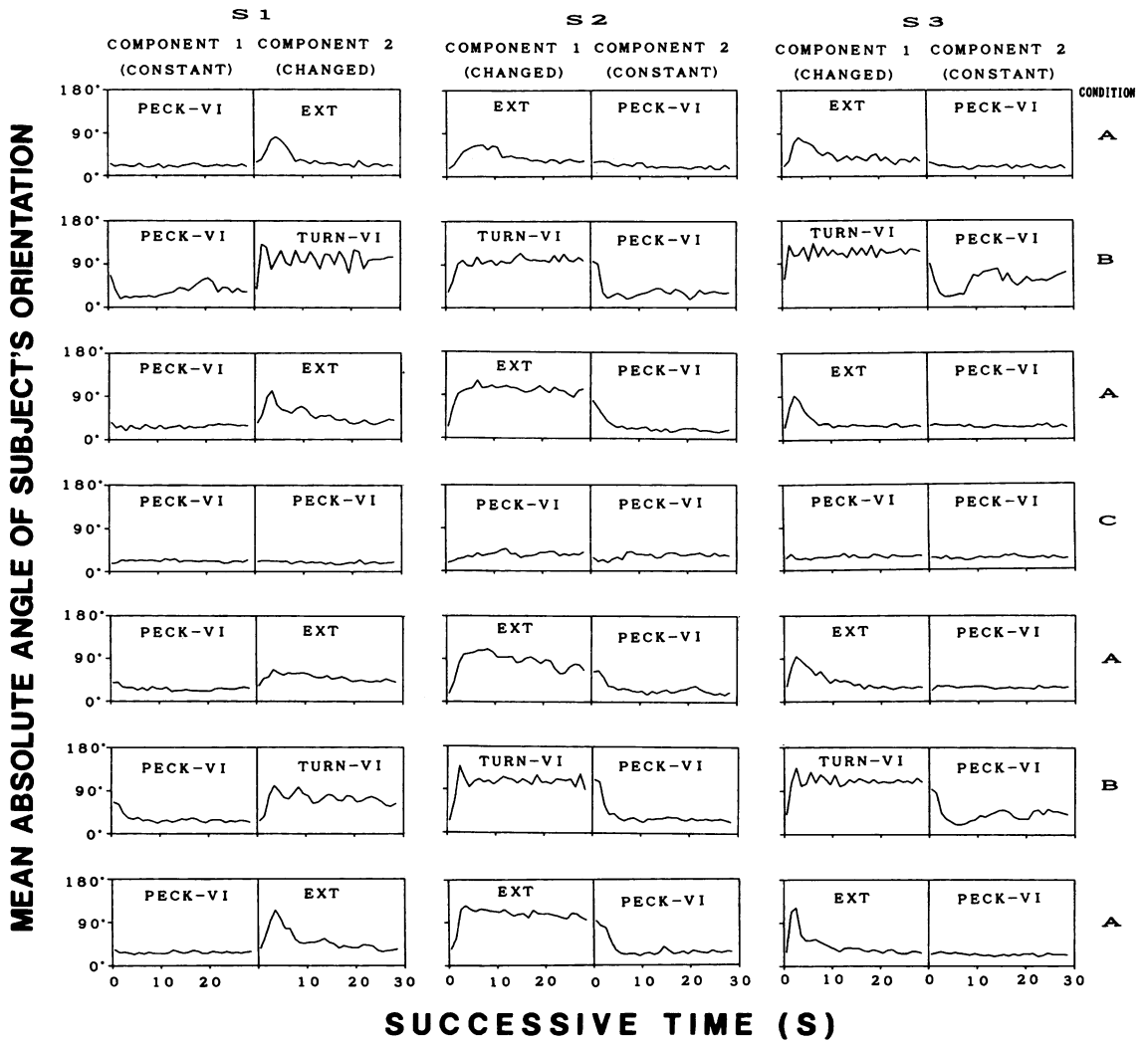


Fig. 5. The mean absolute degrees of angular deviation during the constant component just after a change to that component and those in the changed component following a constant component. The data are shown from top to bottom for each subject.

Sweeney (1987) failed to obtain clear negative behavioral contrast for the key-peck response when a treadle-press response was reinforced under the changed component.

There are several possible reasons for this different outcome. First, the two discriminative stimuli that indicated reinforcement were presented in different positions by King and McSweeney (1987). In this study, the two discriminative stimuli were presented on one pecking key. In most experiments in which negative behavioral contrast is found, the two discriminative stimuli are located in the same place. Negative behavioral contrast for the key-

peck response may be enhanced by a condition in which the discriminative stimuli are presented in the same position.

Second, the topography of the response reinforced in the other component may affect negative behavioral contrast for the key-peck response. For example, Scull and Westbrook (1973) suggested that one requirement for positive contrast is that topographically similar behavior be required in both components of the multiple schedule. In general, negative behavioral contrast may be determined not only by the experimental condition but also by the type of responses. Therefore, to test the gen-

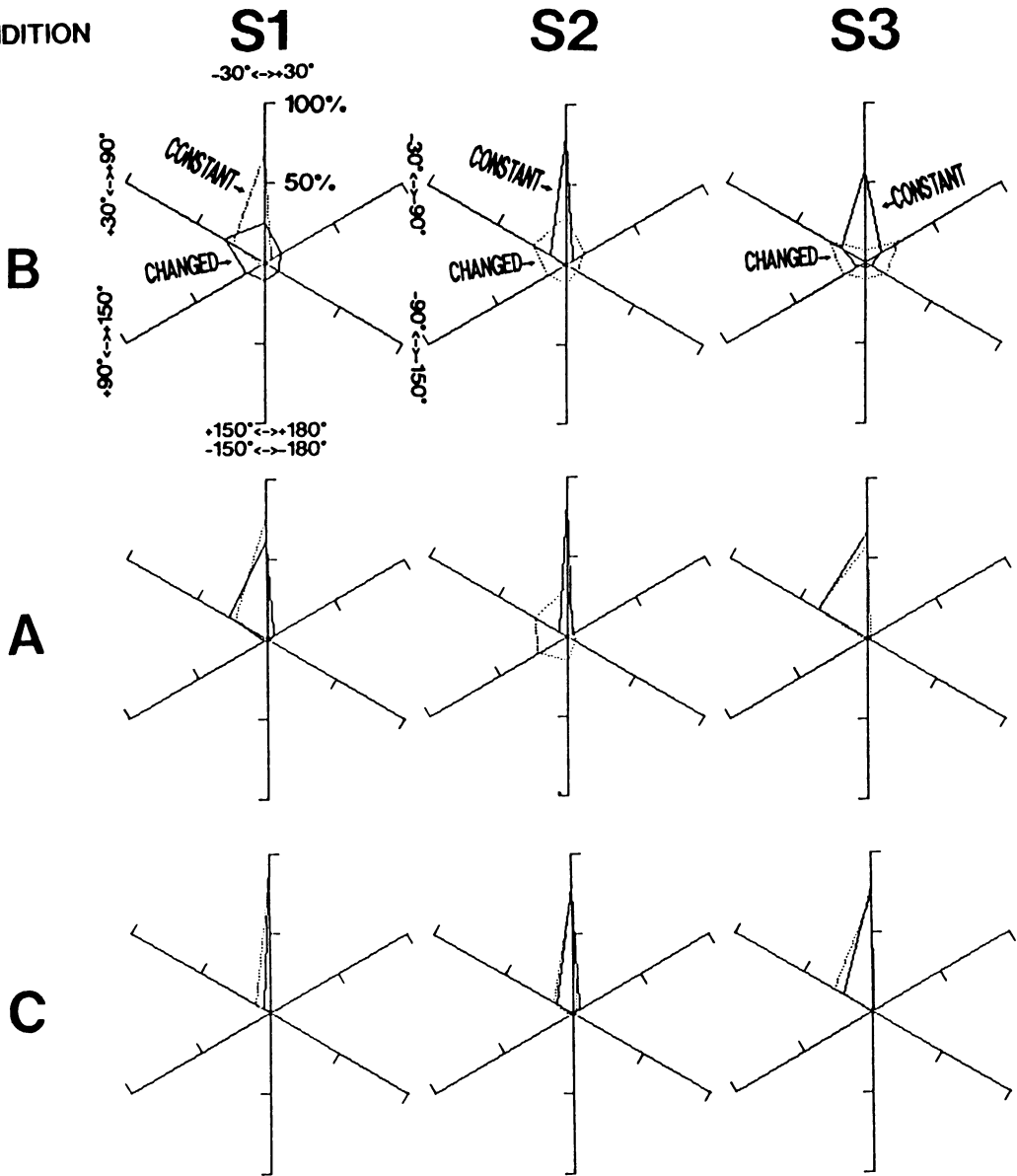


Fig. 6. The percentage of time that the subject oriented its body to the angle. Each axis is for a range of 60°.

erality of behavioral contrast, we should examine a larger variety of responses. The present system may be useful as a tool for examining behavioral contrast across responses that contain changes in angle and position of the body.

The present system detected an initial temporal increase in absolute angle of orientation just after the change from the VI to extinction. Because pigeons cannot peck the key when the angle is large (i.e., when they face away from the key), this phenomenon may be a major

factor responsible for negative local contrast, the decrease in rate of response that is observed just after the component is altered from a rich schedule to a lean schedule. Hearst and Jenkins (1974) asserted, according to their sign-tracking hypothesis, that animals will tend to go away from stimuli that predict a decrease in the frequency of presentation of positive reinforcers. The tendency may be strongest just after the component is changed from VI to extinction. If this is true, negative local con-



trast may result. The initial turning away during the extinction component should be examined further.

Although the rate of key pecking during the constant component was lower in Condition C than in Condition A, the means of absolute angular deviation during the constant component under those two conditions were almost equal. This indicates that the decrease in rate of key-peck responses during the constant component in Condition C might not have been caused by a change in the subject's orientation away from the discriminative stimulus on the pecking key (cf. Hearst & Jenkins, 1974). The decrease in rate might have been caused by inhibition of elicited key-peck response in Condition C or by the other factors (cf. Rachlin, 1973; Schwartz, 1975).

An analysis of the percentage of time that subjects orient towards a particular angle may produce useful data for analyzing time allocation in some experiments, such as concurrent schedules in which subjects peck either of two keys. Because subjects must approach and orient towards the key in order to peck the key, measures of angle and position may provide a more accurate indication of time allocation.

In previous studies of operant behavior, only a few types of responses have been examined, such as the key-peck response for pigeons and the lever-press response for rats and monkeys. It is unclear from existing data whether topographically different responses demonstrate similar phenomena in the same situation. More studies are needed to reexamine various well-known phenomena with more types of responses. The automated system used in this experiment makes such studies more practical.

In summary, the present results suggest that an avoidance response to the discriminative stimulus in the constant component is not the primary factor for negative contrast, but may contribute to negative local contrast. In addition, the system used here may be useful as a tool for the analysis of the other activities that microswitches cannot detect.

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